



WARD & SMITH - A NEW ASTRONOMICAL INSTRUMENT - LONDON 1735

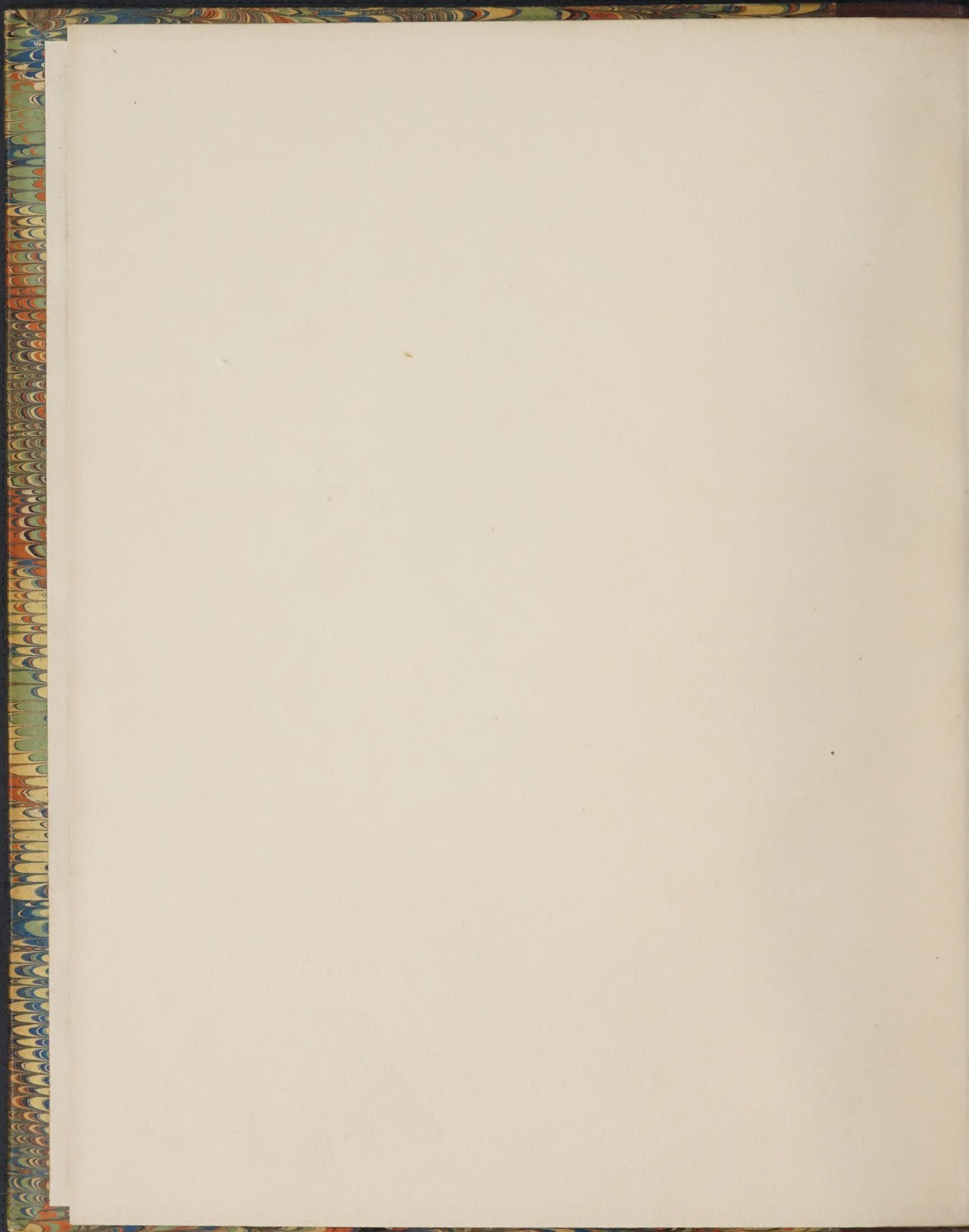


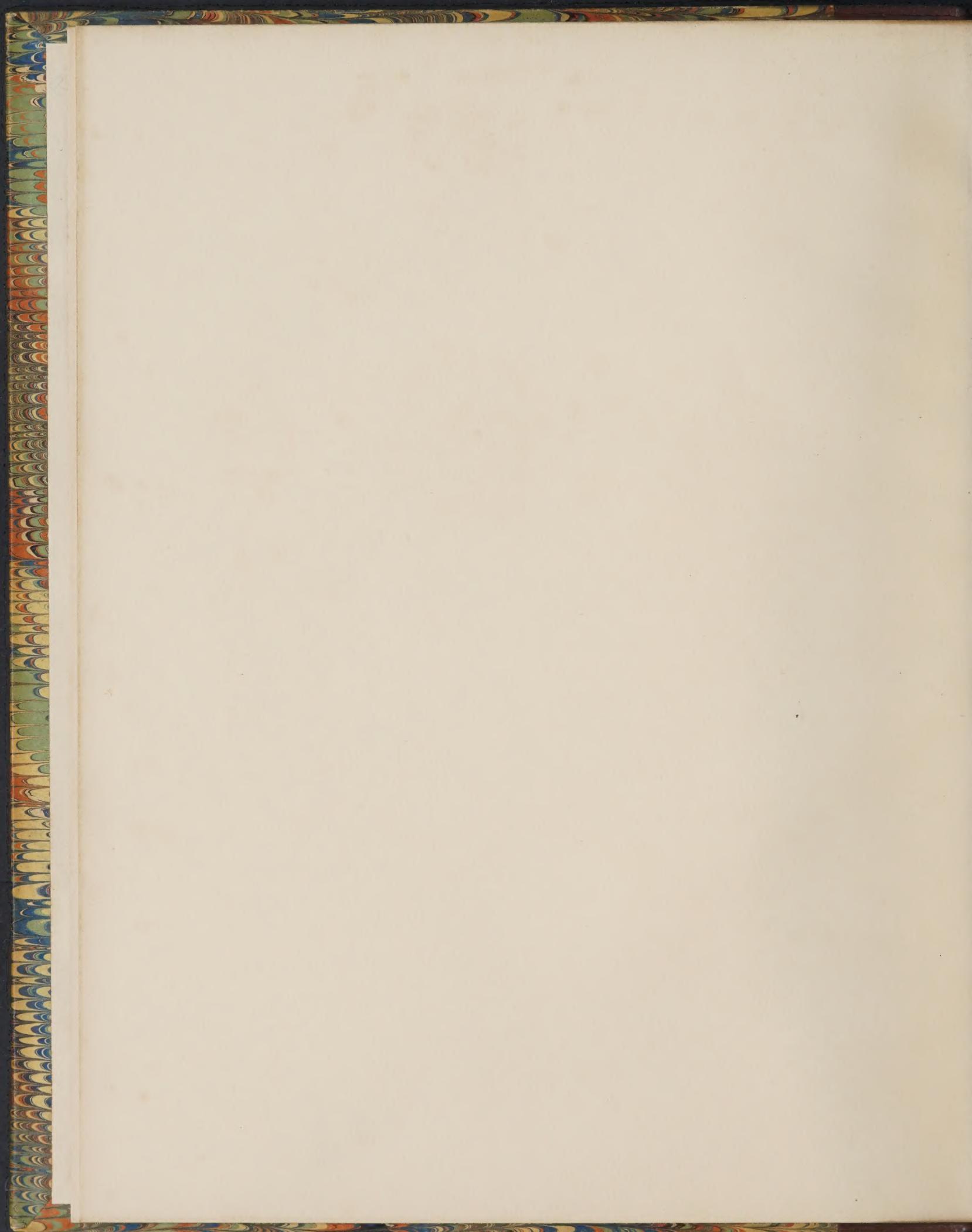




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THE
DESCRIPTION and USE
OF A NEW
Astronomical Instrument,
For taking ALTITUDES of the SUN and STARS
at SEA,
WITHOUT an HORIZON;
TOGETHER WITH
An Easy and Sure METHOD of OBSERVING
The *Eclipses of Jupiter's Satellites*,

Or any other PHENOMENON of the like Kind, on *Ship-board*;

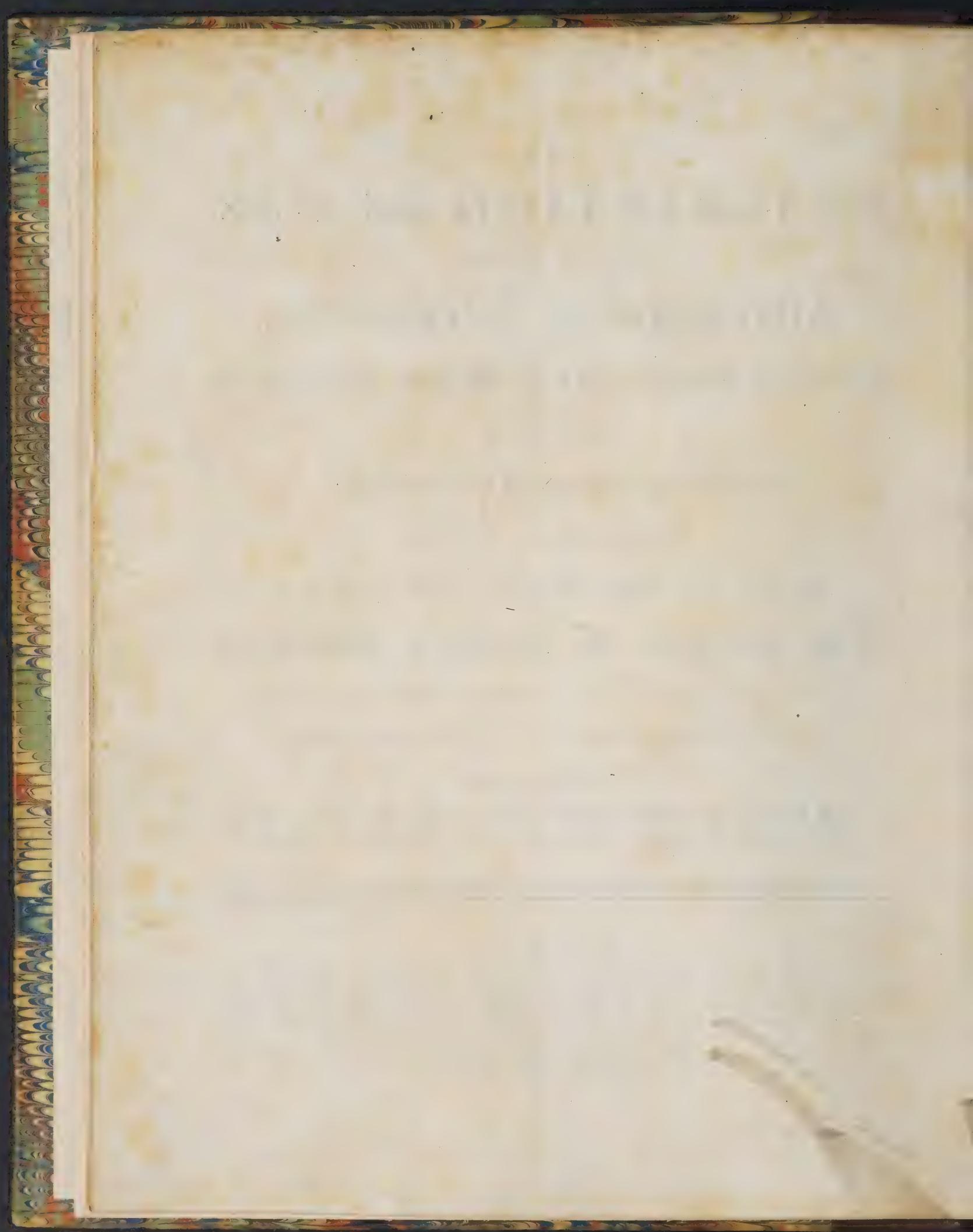
In order to determine the DIFFERENCE of MERIDIANS at SEA.

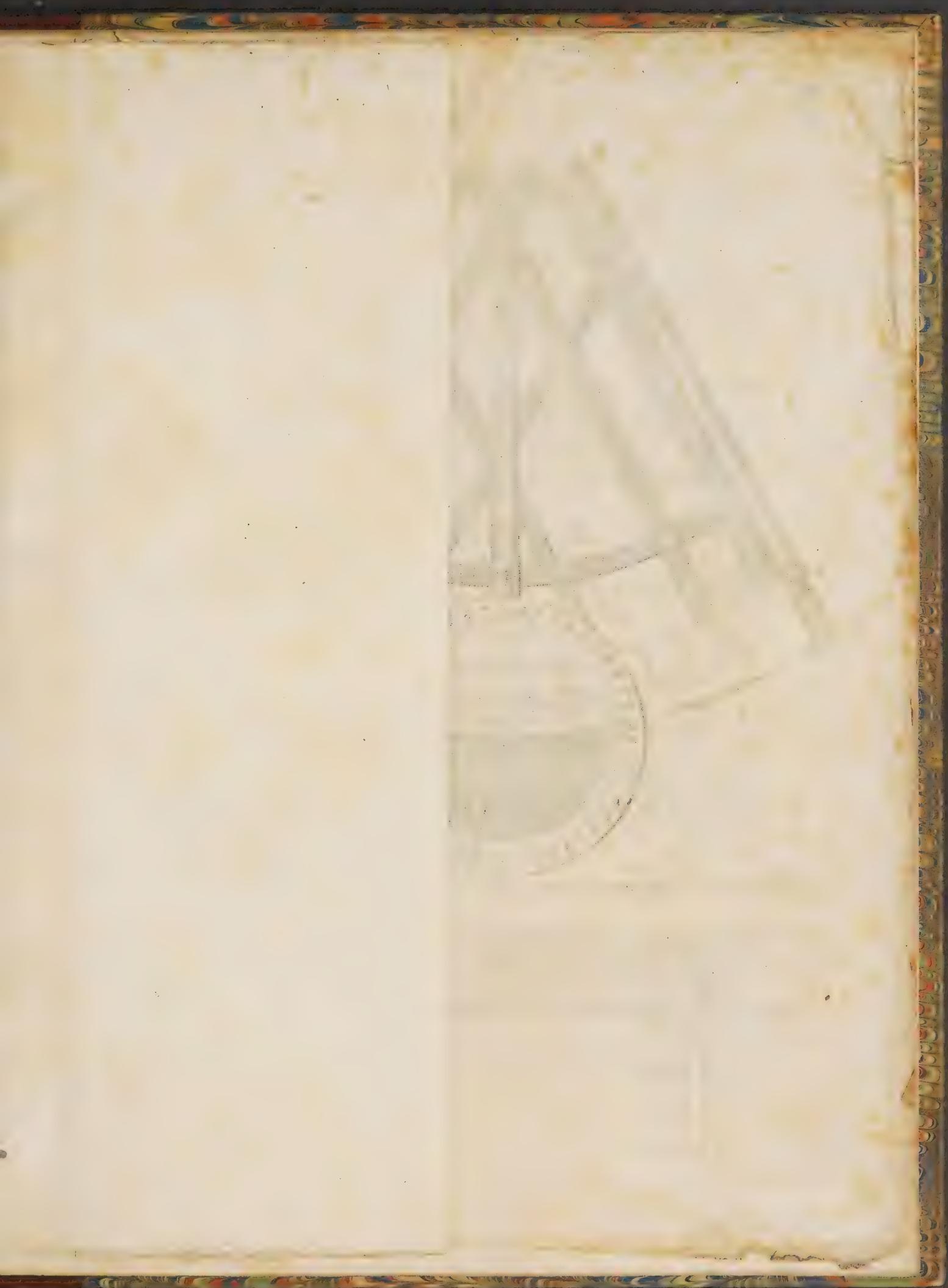
To which are added,

T A B L E S for computing the *Times* when the *Eclipses* of the
First Satellite of *Jupiter* happen under the *Meridian of London*.

L O N D O N:

Printed for G. STRAHAN, W. MEADOWS, and J. CLARKE, in *Cornhill*; C. RIVINGTON, W. INNYS and R. MANBY, in *St Paul's Church-Yard*; J. MANN, *Optician*, at the *Archimedes*, and J. SENEX, against *St Dunstan's Church* in *Fleet-street*; C. WARD and R. CHANDLER, between the *Temple-Gates*, and at their Shop in *Scarborough*; J. ROBINSON, next the *One Tun Tavern*, and T. HEATH, *Mathematical Instrument-Maker*, next the *Fountain Tavern* in the *Strand*; R. WILLIAMSON near *Gray's Inn Gate*; and J. STAGG in *Westminster-Hall*. 1735.





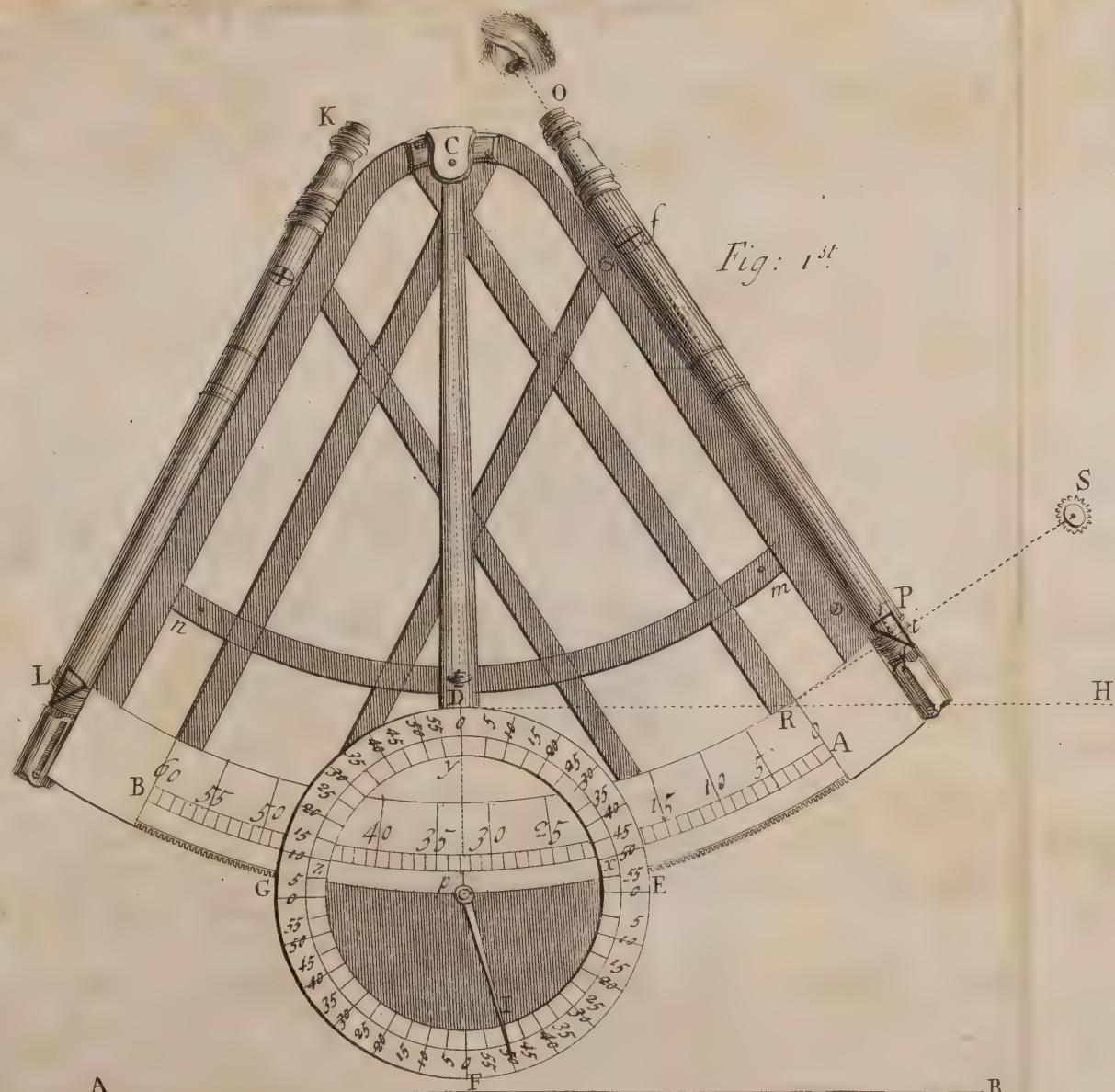


Fig: 1st

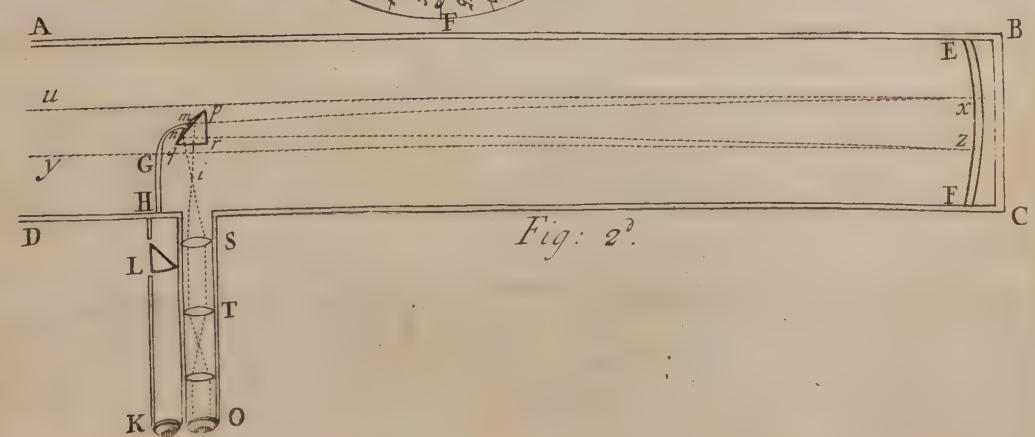


Fig: 2^d

T O

*The Right Honourable Sir CHARLES WAGER, KNT.
First Lord Commissioner of the Admiralty; Admiral of the White
Squadron; and Master of the Trinity-House, &c.*

*The Right Honourable ARTHUR ONSLOW, Esq; Speaker
of the Honourable House of Commons; and Treasurer of the Navy, &c.*

Sir JOHN NORRIS, Admiral of the Red Squadron.

Sir GEORGE WALTON, Admiral of the Blue Squadron.

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*NICHOLAS SANDERSON, L L D. Lucasian Professor
of the Mathematics in Cambridge.*

*ROBERT SMITH, L L D. Plumian Professor of the
Mathematics in Cambridge.*

The Honourable Sir THOMAS HANMER, Bart.

The Honourable WILLIAM CLAYTON, Esq;

*Commissioners appointed by Act of Parliament, for the Discovery of the
Longitude at Sea, and for examining, trying, and judging of all
Proposals, Experiments, and Improvements relating to the same.*

GENTLEMEN,

WE beg leave, in the most respectful manner, to lay before You, *An easy and sure Method of ascertaining the Longitude, or Difference of Meridians at Sea, within a Degree of a Great Circle, or sixty Geographical Miles, by means of certain Instruments contrived for that Purpose; the Description whereof we think proper to exhibit in this public manner, in order*

order to disappoint the Intentions of some Persons, who are disposed, on all occasions, to assume to themselves the Credit of other Men's Inventions ; as well as to prevent the Trouble and Inconvenience that might arise from such a *Pretence* of their having *hit* on the same *Discovery*.

We are not insensible, that a *Proposal* of this kind is attended with many *Difficulties* and *Discouragements* : The various *Idle* Schemes and *Chimerical* Projects that have been offered as *Discoveries* of the *Longitude*, have so much prejudiced Men's Minds against all Propositions of this sort, and brought so much Disgrace on the Projectors, that every *Attempt* to solve this *valuable Problem*, is now ridiculed as the effect of a weak, or a distempered Brain : The Thing itself has been so long the *Reproach of Art*, and every *Essay*, how promising soever, has hitherto proved so *unsuccessful*, that the greatest Part of Mankind look on it as an *Impossibility* ; for which Reason, we expect, what we say on this Subject, will be treated, by many Persons, with Ridicule and Contempt.

However, we shall endeavour to remove this Prejudice, by shewing, that the *Discovery of the Longitude at Sea*, is neither *impossible*, nor *impracticable*.

With regard to it's *Possibility*, Mathematicians are well enough satisfied in that Point ; more especially, the *Method* we are about to *propose*, and hope to render *practicable*, has long been approved of, and recommended by the best Astronomers, *as true in Theory, tho' very difficult in Practice* ; which we could readily make appear, by several Testimonies in the *Philosophical Transactions*, and *elsewhere* ; but we shall content ourselves, at this Time, with quoting a Passage or two, from the late Reverend Mr *Flamstead*, and the present Royal Astronomer of *Greenwich*, the Learned Dr *Halley*, who are not more universally, than deservedly, celebrated for their consummate Knowledge and Skill in these Affairs.

Mr *Flamstead's* Words are these ; (*Phil. Trans.* No. 151. p. 302.)
 " The Eclipses of Jupiter's Satellites have been esteemed, and certainly
 " are a much better Expedient for the Discovery of the Longitude,
 " than any yet known, by reason that they happen frequently ; and are
 " easily observable with a Telescope of twelve Foot, or for need, with
 " one of Eight.

Dr *Halley*,

Dr *Halley* speaking of the Method that the Royal Academy at *Paris* used, for settling the Geographical Situation of Places in *France*, says, (*Phil. Trans.* No. 214. p. 237.) “ *The Method they have used to determine the Longitude of their Places, is by the Observations of the Eclipses of the First Satellite of Jupiter, which they find almost instantaneous, and with good Telescopes, discernable, almost to the very opposition of Jupiter to the Sun; and it may be said, that this Account of the Longitudes observed, has put it past doubt, that this is the very best way, could portable Telescopes suffice for the Work: And could the Satellites be observed at Sea, a Ship at Sea might be enabled to find the Meridian she is in, by the help of the Tables Monsieur Cassini has given us in this Volume, discovering with great exactness the said Eclipses, beyond what we can yet hope to do by the Moon, tho’ she seem to afford us the only Means practicable for the Seamen. However, before Sailors can make use of this Art of finding the Longitude, it will be requisite that the Coast of the whole Ocean be first laid down truly; for which Work this Method by the Eclipses of Jupiter’s Satellites, is most apposite; and it may be hoped, that either a true Geometric Theory of the Moon may be discovered, by the Time the Charts are compleated, or else, that some Invention of Shorter Telescopes may suffice to shew the Eclipses of the Satellites at Sea”.*

Now, with respect to the *Practicability* of this *Method*, here the great *Difficulty* lies; *bic Labor hoc Opus!* In order, then, to render the same *practicable* at *Sea*, and serviceable to our Purpose, *Two Things* are principally required, *viz.*

First, In whatsoever *Place* the *Ship is*, to be capable of determining, there, the *Time of the Day, or Night*, to a sufficient Degree of *Exactness*.

Secondly, To be able to observe the *Eclipses of the First Satellite of Jupiter*, (or any other *Phænomenon* of the like kind) at *Sea*, the *precise Time* of whose Appearance can be *known* or *predicted*, at some other certain *Place*, or *fixed Meridian*.

As to the *first* of *These*, *viz.* The *Way* of finding the *true Time of the Day, or Night*, at the *Place* where the *Ship is*; altho’ most of the *Writers* on this *Head*, have taken it for granted that the *Thing* is very *easy*, yet, we apprehend, it cannot be obtained *sufficiently exact*, by any of the *common Methods* practised at *Sea*: One

of the best, and most approved, is that by the *rising of the Sun*, or *a fixed Star*, proper Allowance being made for Refraction, &c. And this needing no Instrument, would, no doubt, be very *easy*, and come near enough the *Truth*, if this *Appearance* could be accurately observed, as *often* as need should require: But this we are well assured is not to be done, by reason, that such *accurate Observations* can *rarely* be made, for *want* of a clear, perfect, and distinct *Horizon*. Wherefore, that we might obtain this *Requisite* with greater *Certainty*, and more *Frequency*, we contrived a *New Instrument*, whereby we are enabled, with much Facility, to take the *Altitudes* of the Sun and Stars at Sea, *without* an *Horizon*, to less than Five Minutes, and consequently to determine the *Latitude* of the *Place*, and the *Time* of the *Day*, or *Night*, at Sea, sufficiently *exact* for all the Purposes of Navigation; especially, if the *Height* of the Sun, or Star, be taken, to answer the *last* Intention, when it is at such an *Elevation*, as to have little or no *Refraction*; and is likewise *near* the *Prime Vertical*, for then it's *Altitude* is *changed* most sensibly, and considerably, in a very *small* space of *Time*.

This *INSTRUMENT* we shall now describe; and tho' it may be composed of any proper *Materials*, and of any *Radius*, yet, we judge, it will be most *convenient* for *Use*, at *Sea*, to make it a *Sextant of Brads*, cast in the *Form* exhibited by the *Scheme*; (See *Fig. 1.*) Let the *Radius CA*, of it's greatest *Arch AB*, be twelve *Inches*, (or thereabouts) which *Arch* is *graduated* only into *single Degrees*: The outermost *Edge* thereof must be curiously divided, or cut down, into two Hundred and forty fine *Teeth*, equal to, and at an exact Distance from, each other; of which, there will consequently be *four* in the space of *one Degree*: On the *Center* of this *Arch C*, is suspended upon an *Axis* that turns in *Pewet Holes*, a strong *Label*, or *Pendulum* of *Brads*, *C D E F G*, fifteen *Inches* long, which is *elevated* a little above the *Surface* of the *Sextant*, by means of a *Roller* fixed to it, which runs on the *lesser Arch*, *m n*, in order to avoid *Friction*, as much as possible, in it's *Vibration*: The *upper Part* of this *Pendulum CD*, is made in the *Form* of a *flat Ruler*, of the length of nine *Inches*; the *lower Part* of it, *D E F G*, is a *Circle*, six *Inches* in *Diameter*, about one *Third* of whose *Area*, or the *Segment* thereof, *x y z*, lying directly over the *great Arch* of the

the Sextant, is left *open*, that the Degrees thereon graduated may appear thro' it ; and the *Chord* of this Segment x z , has it's thickness filed away, or sloped down, to a *Bevel* or *Chamferd Edge*, which is made *circular*, so that it may *apply* close to the said graduated Arch *A B*. The remaining *Part* or *Segment* of this Circle, *E G F*, is filled up with solid Brass, to give it a sufficient weight. Each *Quadrant* of the *Rim*, or *Periphery* of this Circle *D E F G*, is divided and numbered into sixty *equal Parts*, or *Minutes*, like a *Dial-Plate* : At the *Center* of this Circle *p* is placed, in a proper manner, a *Pinion* of sixteen Leaves, exactly proportioned to the Teeth of the great Arch, in which it plays freely, and turns *once* round precisely, whilst the *Label*, or *Pendulum*, passes over the space of *four Degrees*: This *Pinion* carries round with it an *Index*, or *Hand*, *I*, fixed upon it's *upper Part*, which, in it's Revolution, *marks*, or *points to*, the *Minutes* engraved on the *Periphery*, or *Dial-Plate* aforesaid ; the Degrees being *shewn*, or *cut*, at the same Time, on the Arch of the Sextant, by a *right Line*, (drawn for that Purpose upon the Slope, or *Chamferd Edge*, from the *Center* of the *circular Part* of the *Label*, or *Pendulum*) whilst it hangs *perpendicular* to the *Horizon*, which it will do most constantly and exactly, notwithstanding the small Friction occasioned by the *Pinion*, and the *Axis* on which it turns ; provided the *Instrument* be fixed in a *vertical Plane*, with it's *Arch* downwards, in the *Time* of *Observation*.

From what has been said, it is easy to perceive, that an *Instrument* thus formed, ought to be held, when it is made use of, as *steady* as possible, least the *Pendulum* vibrate so much, as to cause a great *Uncertainty*, or *Error*, in the *Angle* to be measured : And here we must acknowledge, a considerable *Difficulty* occurred in this *Matter* ; for, if plain *Sights*, or a *Telescope* in the *ordinary Way*, were fixed on one of the *Radii* of this *Sextant*, with it's *Object-Glaſs* towards the *Center*, and it's *Eye-Glaſs* next the *Arch*, it will be necessary to *elevate* the *Arch*, and consequently the whole *Instrument* above the *Eye*, in such a manner, as to put the whole *Body* of the *Observer* into a most *irksome* and *unsteady Posture* ; by reason, that the *Arms* must be extended upwards, and the *Head* reclined backwards, in order to view an *Object* of any *considerable Altitude* : In such an *uneasy Position*, it is scarce possible to hold any *Instrument* so *steady* as is *requisite*, especially

on *Ship-board*, which any one may be readily convinced of that is disposed to make the Trial: Wherefore, we found it would be absolutely necessary to contrive some other Method, whereby, an Observer at Sea might be enabled to hold this Instrument with less *Uneasiness*, and more *Steadiness*; and this we effected in the following manner.

Instead of a Refracting Telescope to be placed on it's Radius, as has been usual, we devised a *New Instrument*, which for *Distinction* sake, and upon account of the *singular Use* we design to make of it in Astronomical Observations, we shall take the liberty to call an *Astroscope*. An *Astroscope* is thus formed.

In lieu of an Object-Glaſs, let there be made a *triangular Glass-Prism*, one Face whereof is a *Segment*, or *Portion* of the Convex Surface of a *Sphere*, whose Radius is nearly one half of the Length of the designed Instrument; and the two other *Faces* *Plane-Quadrilateral Figures*, three of whose *Sides* are *Rectilinear*, and the fourth *Side*, an *Arch* of a Circle: If the *Subtense* of the Arch be considered as one *Side*, instead of the *Arch* itself, then, one of the said Faces will be a *Square*, and the other (which we shall call it's *Base*) a *Parallelogram*, whose Length is to it's Breadth, in a subduplicate *Ratio* of Two to One. The *Angle* of the Prism in which these *Plane Faces* *meet*, must be *Forty-five Degrees* exactly; and then, if we imagine a *Plane* to pass through the *Periphery* which terminates the *spherical Face*, it will be perpendicular to, or make a *Right Angle* with, the *square Face*; and be *inclined* to the *Base*, or *Parallelogram*, in an *Angle* of *Forty-five Degrees*.

In one End of a braſs *Tube* we fix a *Convex-Lens*, or *Eye-Glaſs*, of a shallow Charge, and a great Breadth; and at the other End, the *Prism* thus formed, with it's Convex Face turned *towards* the *Eye-Glaſs*, in such a manner, that the *Axis* of the *Tube* passes through the *middle* of it, at right Angles, and inclined to the *Base*, or *Parallelogram* of the *Prism*, in an *Angle* of *forty-five Degrees*; then will the *other Plane Face*, or *Square*, of necessity, lie *parallel* to the *said Axis*; directly over which, to give a *Passage* to the *Rays* of *Light* into this *Instrument*, a *circular Hole*, or *Aperture*, of a proper *Magnitude*, is cut thro' the *Side* of the *Tube*.

Thos

Those who are skilled in Optics will readily perceive, that if the Rays of Light which flow from any *one Point* of an Object vastly distant, be considered as *parallel* to each other, at their Incidence upon the outermost Face of the Prism, and pass through it at *Right Angles*, they will be all *reflected* at it's Base, in such a manner, as to proceed in Right Lines *parallel* to the Axis of the Tube, till they arrive at the Convex Face, where they will, at their Emergence, be *refracted*, so as to *converge* towards a *Point*, nearly distant therefrom, by the Diameter of the Sphere to which the said Convex Surface was ground, and will *there* form a distant *Image* of the Object; which *Point* must therefore be the common *Focus* of the Prismatic-Object-Glass and the Eye-Glass; where two *Hairs* are to be placed at Right Angles to each other, intersecting mutually in the Axis of the Tube.

By an *Astroscope* thus formed, this peculiar Advantage is obtained, that we are not obliged to *elevate* it, or hold it *above* the Head, in a troublesome Position, in order to view any Object by it; for it is evident, from it's Construction, that the whole Tube, in the Time of Observation, must be *depressed* below the Eye, till it's Axis lie in such a Situation, as to be *perpendicular* to a Right Line drawn to it, or imagined to be so, from the Object to be observed; for then the Image of that Object will be distinctly seen by an Eye looking upon it through the Eye-Glass: And here it is to be noted, that all Objects will appear in this *Astroscope*, *Erect*, as in a Day-Telescope, but *inverted* with regard to *Right* and *Left*.

On *each* of the outermost *Radius* of our Sextant CA and CB, or parallel thereto, we place an *Astroscope*, with it's Eye-Glass towards the *Center*, and the Prismatic-Object-Glass towards the *Arch*: And thus the whole *Instrument* will be *finished*, and *adapted* for Observation, or taking Altitudes at Sea, or Land, *without* an *Horizon*. We shall in the next Place explain the

M A N N E R of U S I N G it.

Let the *Observer*, either sitting or standing, hold the *Instrument* in *both* his *Hands*, with it's *Arch* *downwards*, in the same *vertical* *Plane* with the *Object*, and placing one Eye to that *End* of the

C

Astroscope

Astroscopic O, which is next the Center, let him *elevate* and *depress* the whole *Infirument*, till the Object becomes *visible*, or *appears* at the *Intersection* of the Hairs, in the *Focus* of the *Astroscopic*; upon which it is to be kept as *steady* as possible, till the Pendulum has nearly finished it's *Vibration*, or till it's *Motion* is almost ceas'd. In this the *sole* *Difficulty* lies, which will easily be overcome by a little *Custom* and *Practice*; so that a Person some time *accustomed* to make *Observations* with it, on *Skip-board*, will be able to hold it so *steady*, that the *Vacillation* of the Pendulum will *seldom* cause an *Uncertainty* of more than three or four Minutes, in the Angle to be taken: And if the *Motion* of the Ship should be so *great*, at some times, as to make the *Index* *vibrate* more than is here mentioned, yet the *Extremes* of that *Vibration* may be *noted*, and the *mean* *Number* will be that which is required.

By the *Astroscopic*, if it be made (as it should be for this *Use*) to take in an *Area*, or *Field* of seven or eight Degrees, an Object may be readily found in this manner, and brought to the *Intersection* of the Hairs in it's *Axis*; the Pendulum then settling itself *perpendicular* to the *Horizon*, may be stopt there by the Finger, or a *Catch* for that *Purpose*; and the *Degrees* and *Minutes* shewn thereby, will give us the *true Altitude* of the Object, *quam proximè*, in case that *Astroscopic* was made use of which is fixed on the *Radius* C A, drawn from the *Center* C to A, the *beginning* of the *Degrees* graduated upon the *Arch*: But if the *other Astroscopic* K L is used, (which will be *necessary* when the Object is elevated more than sixty Degrees above the *Horizon*) then the *Pendulum* in it's *perpendicular* *Situation*, will mark the *Degrees*, and the *Index* will shew the *Minutes* of the Object's *Distance* from the *Zenith*.

D E M O N S T R A T I O N.

LET S represent any Object seen in the manner before described, at the *Intersection* of the Hairs f, in the *Focus* of the *Astroscopic*, by the Eye of an *Observer* placed at O; draw the *Right Line* S q, described by a *Ray* flowing from the *Center* of the Object, and passing through the *middle* of the *outermost Face* of the *Prism*, at *Right Angles*, to the *Point* q in it's *Base*, where it will be *reflected*, in such a *manner*, as to become *coincident* with the *Axis* of the *Astroscopic*, making

making the Angle Sqf , a Right one (by the Construction of the Prism already given). Continue the Line Sq till it meet the Radius of the Sextant CA in R , then will the Angle SRC be likewise Right, because RC is parallel to qs (by hypothesis). Through the Point R , draw the Right Line HD , perpendicular to the Plumb-line of the Pendulum CD ; which will therefore be an Horizontal Line, and the Angle HRS , by consequence, is the true Altitude of the Object S . Now we are to prove, that the Angle RCD , whose Measure is the Arch Ap , cut by the Pendulum or Plumb-line CD , produced to p , is equal to the aforesaid Angle HRS , or the true Altitude of the Object. By the thirty-second Proposition of the first Book of Euclid, the outward Angle HRC , that is, the Angle $HRS +$ the Angle SRC , is equal to the two inward and opposite Angles taken together, viz. $RCD + RDC$; but the Angle SRC is equal to RDC , for they are both Right (by Construction as was shewn above); therefore the Angle HRS is also equal to the Angle RCD (Euclid, Axiom 3.) Q. E. D.

In like manner it may be shewn, that the Angle comprehended between the Radius BC and the vertical Line of the Pendulum CD , will be equal to the Zenith-Distance of any Object, seen or observed by means of the other Astroscope KL , which lies parallel to the Radius CB , drawn from the Center C to the End of the Degrees on the Arch at B .

There is another Manner of observing the Sun's Altitude by this Sextant, when He shines clear, which is thus: Let the Observer hold the Instrument as before, in the same vertical Plane with the Object, it's Arch being downwards, and the Face of it turned towards him; then let him elevate and depress it, till a Convex Lens fixed upon one of it's Radii, form a bright Spot, or Image of the Sun, at the Intersection of two Lines drawn on a Plane, that is placed in it's Focus, at Right Angles, to the Axis of the Lens; and the Pendulum hanging perpendicular at the same time, to the Horizon, will shew the Degrees and Minutes of the Sun's Altitude, or his Distance from the Zenith, in the same manner as before.

It is scarce needful to mention, that if instead of a Sextant, the Instrument be made a Quadrant, one Astroscope placed on either of the Radii, will suffice to observe Objects at all Degrees of Altitude. We may likewise add, that for common Use at Sea, 'twill be sufficient

cient to graduate this *Instrument* to every five Minutes, which may be done without any *Teeth*, *Pinion*, or *Index*; for the *Bevil*, or *Chamferd Edge* of the Pendulum, which cuts or applies to the *Degrees* of the great *Arch*, may be divided after the manner of *Nomius*, so as to *shew* the Angle to every five Minutes: And this Method will render the *Instrument* very *cheap*, as well as extremely *simple*, and sufficiently *accurate*.

Having given the *Description* and *Manner* of *using* this *Instrument*, it may be proper to enumerate some of those *Advantages*, upon account of which, it is *preferable* to any other that has hitherto been *invented* for taking the *Altitudes* of *Objects* at *Sea*.

The *first* *Advantage*, and not the *least*, results from the very *Nature* and *Construction* of this *Instrument*, whereby we are *enabled* to find the *Latitude* at *Sea*, much *more frequently* than by any other; a thing of such *extraordinary* *Use* in *Navigation*, that it is, in the *Opinion* of many *Persons*, as much wanted and desired, for the *Safety* of *Ships* and *Preservation* of *Mens Lives*, as the *Longitude* itself: Now, it is but too well known, by long and sad *Experience*, that the very *best* *Instruments*, if they *require* an *Horizon*, are often rendered *useless* by the *want* of it, when the *Need* of them is greatest, and the *Danger* most *imminent*; as for instance, in coming in with the *Land* or *Coast* of this *Island*, in *Voyages* from the *East* and *West Indies*, &c. for in our *uncertain* *Climate* 'tis rare to have a clear and perfect *Horizon*, and that too must be seen when the *Sun* is upon the *Meridian*, otherwise 'tis of no *Service* for this *Purpose*; by which means a very able *Commander* assures us, he has been disappointed of obtaining the *Sun's Meridian-Altitude*, from one *Day* to another, for several *Weeks* together, and this in no wise occasioned by *tempestuous Weather*; for *Seamen*, as the *ingenious* *Mr Hadley* observes, (*Phil. Trans.* No. 430. p. 167) "are much oftner sensible of this [Impediment] in calm Weather than in rough." Now the *Necessity* of seeing the *Horizon*, is an *Inconvenience* we have intirely *removed*, insomuch, that if the *Place* of the *Sun* in the *Heavens* is but *visible*, as He shines through a *Cloud*, tho' so faintly as to give *no Shade*, yet an *exact Observation* may be made, and his true *Altitude* obtained, by means of our *Instrument*: But we have yet a much greater *Benefit* by it; for tho' the *Sun* should not be seen

at *Noon-Day*, it may, and often does happen, that the Heavens are *clear* and *serene* at some time of the *Night*: And since, at *all Hours*, there will be *one* or *other* of the most noted of the *fixed Stars*, upon, or near the *Meridian*, the *Opportunities* of taking their *Altitudes*, and consequently of finding the *Latitude* at *Sea*, will be as *frequent* as can be desired.

The *second Advantage* of our *Instrument* is, that we are *enabled* to obtain the *Altitudes* of the *Sun* and *Stars* at *Sea*, *more accurately* than by any other; and this is derived from the same excellent *Property* of it's *Usefulness without an Horizon*. With regard to the *Stars*, we need not say how altogether *insufficient* the *Instruments* hitherto used, are for *this Purpose*; and in taking *Altitudes* of the *Sun*, with the *common Quadrants*, the *Error* that almost constantly arises from the *Indistinctness*, *Obscurity*, and *Uncertainty* of the *sensible Horizon*, when looked at as an *Object*, is much *greater* than is generally believed by those that have made no *Experiments* to *ascertain* it: However, that the *Error* is *considerable*, we are fully convinced, not only by the *Reason* of the *Thing*, but also by the *Experience* of a very skillful and judicious *Navigator*, Captain *Christopher Middleton*; to whom the *Public* is indebted for many curious and useful *Observations*, made in his *Voyages* to *Hudson's Bay*. This Gentleman (whose *Example* it is to be wished *other Commanders* of *Ships* would follow) has *compared* several *Altitudes* of the *Sun*, taken on *purpose*, with *very accurate Instruments*, in *still Water*, both *with*, and *without an Horizon*; and from all his *Trials*, he constantly found a *Difference* between them, and *discovered* an *Error* to be introduced from the *Uncertainty* of the *Horizon* only, which frequently amounted to *thirty Minutes*, or more, and *seldom* to so *little* as *five*: This *Imperfection* has no place in our *Instrument*, which is not *subject* to the least *Error* on this *Account*; and the greatest that can happen thro' the *Unsteadiness* of the *Pendulum*, will *seldom* be so much as *five Minutes*, in the *Hand* of an *Observer* who has *accustomed* himself, for a little time, to the *Use* of it on *Ship-board*.

A *Method* of taking *Altitudes* at *Sea* to so great a *Degree of Exactness*, is of such *Advantage*, not only in finding the *Latitude* of the *Place*, but likewise for solving many *other Problems*; more particularly, that of obtaining the *true Time* of the *Day* or *Night*,

which has hitherto been so *difficult* to accomplish, with sufficient *Certainty*; that Mr *Hodgson*, in his excellent *System of the Mathematics*, Vol. I. p. 383. says, “ *Whoever can contrive any way to take the Height of the Sun, or any fixed Star, at Sea, to one or two Minutes, may fairly be entituled to a Share of the Discovery of the Longitude, and ought to have a proportional Reward.* ”

With respect to the *Accuracy* of our *Instrument*, we shall, in this Place, take notice of *another* Property in which it *excels*, and that is, the *manner* of it’s *Graduation*. It has hitherto been very difficult, in Instruments of so *small* a *Radius* as this, to graduate them into Parts *minute* enough for very accurate Observations, without much *Confusion*: This *Defect* we have remedied, by a *new Method* of dividing the *small* Space of a *Degree*, more exactly, minutely, and distinctly, than can be done by any of the common ways in Use: Hence it is that our *Sextant* is exceeding *accurate*, tho’ the *Radius* be very *small*; and the *Minutes* are as *visible*, and as easily *distinguished* here, as in other Instruments whose *Size* is ten times as *large*.

A *third* Advantage of this *Instrument* is, that we can obtain the *Altitudes* of the *Sun* and *Stars*, at *Sea*, *more easily* than by any other. Now this *Facility* arises from our having only *one Object* to regard, which we can find most *readily* by our *Astroscope*; whereas, those who make use of an *Horizon*, have this *Inconvenience*, that they must, of necessity, see *two Objects* together, at one and the same time; but *one* of these *Objects*, to wit, the *Horizon*, tho’ it be ever so *clear* and *perfect*, is frequently *lost* by the *Surge* of the *Sea*, or *intercepted* by the *Rising* of the *Billows* between *It* and the *Observer’s Eye*; and all Instruments *whatsoever*, that require an *Horizon*, are unavoidably *subject* to this great *Obstruction*; for it is not, *simply*, the *Motion* or *Unsteadiness* of the *Observer’s Hand*, as some have imagined, which, in this *Cafe*, *disturbs* the *Observation*, so much as the *Interposition* of the *Waves* of the *Ocean*, or the *Swelling* of the *Sea* before-mentioned, that really and absolutely *deprives* us of the *Sight* of the *Horizon*, for some time, permitting it to *return* only by *Fits*, as it were, and *snatching* it again from our *View*, on a sudden. To these *Interruptions* our *Instrument* is not *liable*, which must certainly *recommend* the *Use* of it, and render it *acceptable* to such as have experienced how *tedious*, *troublesome*,

and difficult it is, to *adjust* the *Sights*, or *Vanes* of the common *Quadrants*, for taking *Altitudes* on *Ship-board*.

The fourth, and *last* Advantage, that we shall at present mention, of this *Instrument*, is it's *Usefulness* at *Land*, as well as at *Sea*: Now many Persons who use the *Sea*, will think, perhaps, they receive no Benefit by this Property of it, but a little Consideration will convince them of the contrary; for it has already been hinted, of how great Service it would be, to have the *Coast of the whole Ocean truly laid down*; and we may reasonably *hope*, that an *Instrument* so *portable*, and not at all *cumbrous*, so *accurate*, and not subject to *warp*, or *alter* with the *Weather*, in a word, so *easy*, and even *pleasant* in the manner of it's *Use*, will be sufficient of itself, to *induce* the *Commanders* of *Ships*, and other curious Persons, to take the *Meridional Altitudes* of the *Sun* or *Stars*, at all the *Places* and *Ports* where they come; by which means, they might soon furnish us with great *Numbers* of exact, and useful *Observations* for correcting and ascertaining the *Situation* of *Places* in *Maps* and *Sea-Charts*, to the great Improvement of *Geography* and *Naviga-tion*; to which, if they would also be pleased to add the *Obser-vations* of the *Eclipses* of *Jupiter's Satellites*, which they may with great *Ease* and *Pleasure* do, by means of the *Telescope* hereafter-mentioned, we might soon expect to see those *Arts* advanced to their highest *Perfection*.

We now proceed to the *second Thing* proposed, *viz.* to be able to *observe* the *Eclipses* of the *First Satellite of Jupiter* (or any other *Phænomenon* of the like kind) at *Sea*, the *precise Time* of whose *Appearance* can be *known* or *predicted*, at some other certain *Place*, or *fixed Meridian*.

To this End, we shall here describe the *manner* in which a *Te-le-scope*, *easily manageable* on *Ship-board*, and altogether *sufficient* for this *Purpose*, may be formed.

Let there be made a *Tube*, or hollow *Cylinder* of *Brafs*, A B C D, (*vid. Fig. 2.*) about *four Foot* long, and *four Inches*, or somewhat more, in *Diameter*, dyed as *black* as possible on the *Inside*. At one End of this *Tube*, a metalline *Speculum*, E F, spherically *con-cave*, and *polished* with the *utmost Care*, whose *focal Distance* is *forty-eight Inches*, or thereabouts, must be *fixed*, so that it's

Axis

Axis may coincide exactly with that of the Cylinder : Near the other End of the Tube, which is open, a brass *Arm*, or *Handle HG*, must descend into the middle of it's Cavity, which may be moved nearer to, or farther from, the great *Speculum*, as occasion requires, by means of a *Slider*, to which it is fixed at the Side of the Tube.

To the End of this *Arm* is cemented a small oval *Plane*, of polished metal, or rather a *Triangular Prism* of Glass, pqr , whose uppermost Angle r , is a *Right one*, and the other two are each exactly *Forty-five Degrees* : The *Faces* of the Prism, which meet in the Right Angle, are exactly *square* ; and the *third Face* is a *Rectangular Parallelogram*, whose Breadth is to it's Length, as 1 to the square root of 2. This *Prism* must be placed in such a manner, that a *Ray* reflected from the *Concave Speculum*, may pass thro' the middle of the *square Face* pr , at *Right Angles*, but *inclined* to the *Parallelogram* in an Angle of *Forty-five Degrees*, and it's *Distance* from the *Concave Surface* of the *Speculum EF*, such, that the *Rays* reflected from the *Concave*, xm , zn , after their *second Reflection* at the *Base* of the *Prism*, may *meet* or *unite* in the *Inside* of the *Tube*, at i ; that is, so as the *Distance* of the *Focus i*, from the *reflecting Surface* of the *Prism*, and of that from the *Concave Speculum*, may be equal to the *Focal Distance* of the *Concave Speculum* itself. In the *Side* of the *Tube*, an *Aperture* or *Space* is cut open, to give a *Passage* to the *reflected Rays*, which are conveyed to the *Eye* through three *Convex Eye-Glasses*, placed in a small brass *Tube*, *STO*, at *Right Angles* to the *Great one* : The *Focal Length* of the *Lens* next the *Eye*, is about *one Inch*, and as *broad* as may be : The other two *Eye-Glasses* are exactly *a-like*, and the *Focal Length* of each, about *two and a half, or three Inches* : The *Telescope* thus formed, represents all *Objects Erect*, and they will appear in it as *bright*, as *distinct*, and as *much magnified*, as in the best *refracting one* of *sixteen Foot*, charged with a *four-Inch Eye-Glass* ; and consequently the *Satellites of Jupiter*, will be as plainly and clearly discerned in *one*, as in the *other*. Now we have already shewn, by the *Authorities* we quoted, that if such a *Telescope* could be made *useful* and *manageable* on *Ship-board*, it would not only *suffice*, but also be the *very best way* to determine the *Longitude*, or *Difference of Meridians at Sea* ; but hitherto *no Method* has been *discovered* of making *Telescopes serviceable at Sea*,

Sea, in celestial Observations, when they *magnify* in any considerable Degree. The *Cause* of this must be attributed, either to the supposed *Impracticability* of finding an Object thereby *readily*, or else to the *Difficulty* of keeping it in *View* within the *Telescope*, when it is found, by reason of the rolling Motion of the Ship.

As to the *first Impediment*, which is indeed the *greatest*, we have contrived a Method, whereby it is intirely removed, *viz.* by placing an *Astroscopic*, such as we have before described, at *Right Angles*, to the *Axis* of the great *Telescope*, adjoining to, and of the same Length with, the small *Tube* which contains the three Eye-Glasses: By means of this *Astroscopic*, which takes in a *Field* of seven or eight Degrees, any Object may be *found* most *readily*, and brought near to the Intersection of the Hairs, in it's *Focus*, at which Time the *Eye* may be *removed*, with Ease, to the *Eye-Glass* of the great *Telescope*, (forasmuch as they are close to one another); and the Object will then be *visible* in that also: Those who have *accustomed* themselves to look with *both Eyes* at once, which it is *easy* to do, may place the *Eye-Piece* of the *Astroscopic*, at a *Distance* from the *Eye-Piece* of the *Telescope*, equal to *that* between the two *Eyes* of the *Observer*, after the manner that is practised in a *Binocle-Telescope*; so that while he sees the Object in the *Astroscopic* with *one Eye*, he may likewise view it in the *Telescope* with *the other Eye*.

Now, as to the *second Difficulty* of retaining the Object in *View*, without *losing* the *Sight* of it after it is found, We need only observe, that the *Field* of the Great *Telescope* will be a *whole Degree*, or thereabouts, which is a considerable Space; and also that the *Position* in which this kind of *Telescope* must of necessity be *held*, in the Time of Observation, will, of itself, *contribute* very much to the *Stability* required; for the open *End* of the great *Tube* will be very *little above* the *Eye*, and the remaining *Part* of it will lie *intirely below* it, passing along the right *Side*, or under the right *Arm*; which is a *Situation* most *advantageous* for supporting, managing, and directing it, with little *Trouble* or *Uneasiness*. To this we may likewise add, that it is not in the least *cumberſome* or *unweildy*, either from it's *Length*, or it's *Weight*, which need not be at most, above *fourteen Pounds*; besides, it is *easy* to *support* the lower *End*, in which the great *Speculum* lies, by means of

a *Suspensory* from some Part of the Body, if need require it, so that the Hands shall feel very little of it's Weight, and be at intire *Liberty* to govern and adjust it.

The Learned Dr *Halley* (in the Appendix to the second Edition of *Street's Caroline Tables*) assures us, " *He had found, it only needed a little Practice, to be able to manage a five or six Foot Telescope, capable of shewing the Appulses, or Occultations of the fixed Stars by the Moon, on Ship-board, in moderate Weather*".

Now 'tis evident, that the *Telescope* we have described, takes in a larger Field, and may be *managed* with much *greater Ease* than a *refracting* one of five or six Foot, or even than one of four Foot; for in ours, there will never be any occasion to *recline* the Head, and *extend* the Arms aloft, as 'tis necessary when we look *upwards* at an *Object*, with a *refracting Telescope*; which manner of *Observing* is not only *tiresome*, but likewise creates in the *Observer* so great an *Unsteadiness*, that he cannot, without much *Difficulty*, direct the *Instrument* so as to *keep* the *Object* in *View* for the *smallest Space of Time*.

Upon this Head we shall also cite the Authority of that ingenious Gentleman, Mr *Hadley*, before-mentioned, who tells us, (*Phil. Trans.* No. 430. p. 172.) " *He has been informed, that an Object may be kept in View without much Difficulty, even in pretty rough Weather, through a [refracting] Telescope, magnifying about ten times: Now as such Telescopes seldom comprehend an Area of much more than one Degree in Diameter, or at most one Degree twenty Minutes, it follows, that the Axis of the Telescope is always kept within forty Minutes, at most, of the Object, and that is the greatest Vibration of the Image above and below it*".

Wherefore since our *Telescope* admits of *as large* a Field, and is *less difficult* to *manage* than those *refracting ones*, which have been found by *Experience* to be *serviceable* at *Sea*, we may very well venture to affirm, that a little *Practice* will render it *easy* for an *Observer* to *hold* our *Telescope* on *Ship-board*, so *steady*, that an *Object* once *seen* in it, will seldom be *lost*, or *thrown out* of it, by the *ordinary Motion* of the *Ship*; or if it should sometimes be so, it may quickly be *recovered* again, by the help of the *Astroscope*.

When this *Telescope* is not used, the *Object-metal* must be taken out of the *Tube*, and kept close *shut up* from the *Air*; and if it happen

happen to *soil* or *tarnish*, it may be *cleared* again easily, by rubbing it with soft Leather, or a Rag, and a little *Spirit of Wine*.

We have now shewn how the *Eclipses* of the *first Satellite of Jupiter*, (or any other *Phœnomenon* of the like kind, such as the *Eclipses* of the other *Satellites*, the *Appulses* of the *Moon* to the *fixed Stars*, &c.) may be *observed* at *Sea*, with great *Certainty*, and much *Facility*; as likewise how the *true Time* of that *Observation* may be *obtained*, at the *Place* where the *Ship is*: It only remains, that we be able to *know* the *Time* when the *same Appearance* happens in some other *Place*, or *fixed Meridian*; for Example, at *London*; because, this also being ascertained, the *Difference* of the *said Times* converted into *Degrees* and *Minutes* of the *Equator*, will give the *Distance* of the *Meridians* of those two *Places*, or discover the *Longitude* at *Sea*. Now the *Times* when the *Eclipses* of the *first Satellite of Jupiter* happen under the *Meridian of London*, may be computed exactly by the *Tables* annexed.

We think it proper, before we conclude, to intimate of how great *Use* and *Benefit* a good *Time-Keeper* will likewise be, for ascertaining the *Longitude* of *Places at Sea*, in the *Intervals* between the *Observations* of these *Eclipses*: *Instruments* of that kind are now made in so great *Perfection*, that for the most part, they may be depended on for several *Days* together, without any *considerable Error*. However, since by the *Method* here proposed, we shall be furnished with *frequent Opportunities* of *correcting* and *adjusting* them, as well as of *discovering* how much their *Variation* amounts to, in the *Time elapsed* between one *Observation* and another, when they go too fast, or too slow; we shall consequently know their daily *Deviation* or *Error*, and in what manner to make a proper *Allowance* for it in our *Calculations*; by which means they will become as *useful* to us, for this *Purpose*, as if they had gone most constantly *true*, without any *Change* or *Alteration*; all which is so manifest and obvious, that we need not here enlarge upon it.

This *Proposal*, *Gentlemen*, of a *Method* for *Discovery* of the *Longitude at Sea*, we submit to your *Consideration*, as you have been constituted the proper *Judges* of it by the *Legislature*; who have also been pleased to declare, that such a *Discovery* would be of

particular

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*particular Advantage to the Trade of Great Britain, and an Honour
to this Kingdom.*

We therefore hope, that an *Endeavour* to improve so beneficial and excellent an *Art*, as this of *Navigation*, and advance it to a higher Degree of Perfection, will meet with your *Approval* and *Encouragement*.

We are,

With the greatest Deference, and Regard,

GENTLEMEN,

Your most Obedient, and

Most Humble Servants.

London, January the
20th, 1734.

A B. I. Epochæ Conjunctionum Mediarum Primi Satellitis cum Jove,
sub Meridiano Londinensi.

An.	Conjunct.			An.	Conjunct.		
	med.				Jul.	Jul.	med.
	D.	H.	I.	Cur.			I.
1729	I	6	0	12	715	554	
1730	0	20	11	39	799	468	
31	0	10	23	7	883	382	
32	0	0	34	34	967	296	
33	0	9	14	38	52	215	
34	I	17	54	41	136	133	
1735	I	8	6	9	220	47	
36	0	22	17	36	305	961	
37	I	6	57	40	389	880	
38	0	21	9	7	473	794	
39	0	11	20	35	557	708	
1740	0	1	32	2	642	622	
41	0	10	12	6	726	540	
42	0	0	23	33	810	454	
43	I	9	3	37	895	373	
44	0	23	15	4	979	287	
1745	I	7	55	8	63	205	
46	0	22	6	35	148	119	
47	0	12	18	3	232	33	
48	0	2	29	30	316	947	
49	0	11	9	34	400	866	
50	0	1	21	1	485	780	
1751	I	10	1	5	569	698	
52	I	0	12	33	653	612	
53	I	8	52	37	738	531	
54	0	23	4	4	822	445	
55	0	13	15	32	906	359	
1756	0	3	27	0	990	273	
57	0	12	7	3	75	191	
58	0	2	18	30	159	110	
59	I	10	58	34	243	24	
60	I	1	10	1	328	938	

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

Januarii.						Martii.					
D.	H.	I	II	Num. A.	Num. B.	D.	H.	I	II	Num. A.	Num. B.
1	18	28	36	0	5	1	4	12	23	14	155
3	12	57	12	1	9	2	22	40	59	14	159
5	7	25	48	1	14	4	17	9	35	15	164
7	1	54	24	2	18	6	11	38	10	15	168
8	20	23	0	2	23	8	6	6	46	16	173
10	14	51	36	2	27	10	0	35	22	16	177
12	9	20	12	3	32	11	19	3	58	16	182
14	3	48	48	3	37	13	13	32	34	17	186
15	22	17	24	4	41	15	8	1	10	17	190
17	16	46	0	4	46	17	2	29	46	18	195
19	11	14	36	4	51	18	20	58	22	18	199
21	5	43	12	5	55	20	15	36	58	18	204
23	0	11	47	5	60	22	9	55	34	19	208
24	18	40	23	6	64	24	4	24	10	19	213
26	13	8	59	6	69	25	22	52	46	20	217
28	7	37	35	7	73	27	17	21	22	20	221
30	2	6	11	7	78	29	11	49	58	20	225
31	20	34	47	7	82	31	6	18	34	21	230
Februarii.				Aprilis.							
0	20	34	47	7	82	0	6	8	34	21	230
2	15	3	23	8	87	2	0	47	10	21	235
4	9	31	59	8	92	3	19	15	46	22	239
6	4	0	35	9	96	5	13	44	22	22	244
7	22	29	11	9	101	7	8	12	58	22	248
9	16	57	47	9	105	9	2	41	34	23	252
11	11	26	23	10	110	10	21	10	10	23	257
13	5	54	59	10	114	12	15	38	46	24	261
15	0	23	35	11	118	14	10	7	22	24	265
16	18	52	11	11	123	16	4	35	58	25	270
18	13	20	47	11	128	17	23	4	33	25	274
20	7	49	23	12	132	19	17	33	00	25	279
22	2	17	59	12	137	21	12	1	45	26	283
23	20	46	35	13	141	23	6	30	21	26	287
25	15	15	11	13	146	25	0	58	57	27	292
27	9	43	47	13	150	26	19	27	33	27	296

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

Aprilis.				Junii.			
D.	H.	I	II	D.	H.	I	II
28	13	56	9	27	300		
30	8	24	45	28	304		
Maii.				Julii.			
0	8	24	45	28	304		
2	2	53	21	28	309		
3	21	21	57	29	313		
5	15	50	33	29	317		
7	10	19	9	29	322		
9	4	47	45	30	326		
10	23	16	21	30	330		
12	17	44	57	31	335		
14	12	13	33	31	339		
16	6	42	9	31	343		
18	1	10	45	32	348		
19	19	39	21	32	352		
21	14	7	57	33	356		
23	8	36	33	33	361		
25	3	5	9	33	365		
26	21	33	45	34	369		
28	16	2	21	34	373		
30	10	30	57	35	378		
Junii.				Augusti.			
0	10	30	57	35	378		
1	4	59	32	35	382		
2	23	28	8	36	386		
4	17	56	44	36	391		
6	12	25	20	36	395		
8	6	53	56	37	399		
10	1	22	32	37	403		
11	19	51	8	38	408		
13	14	19	44	38	412		
15	8	48	20	38	416		
17	3	16	56	39	420		
18	21	45	32	39	425		
20	16	14	8	40	429		
22	10	42	44	40	433		

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

Augusti.				Num.		Octobris.				Num.	
D.	H.	I	II	A.	B.	D.	H.	I	II	A.	B.
21	14	55	7	54	580	31	9	59	5	70	758
23	9	23	43	54	584						
25	3	52	18	55	588	Novembris.					
26	22	20	54	55	593	0	9	59	5	70	758
28	16	49	30	56	597	2	4	27	41	71	762
30	11	18	6	56	602	3	22	56	17	71	767
Septembris.						5	17	24	53	71	772
1	5	46	42	56	606	7	11	53	29	72	776
3	0	15	18	57	610	9	6	22	5	72	781
4	18	43	54	57	615	11	0	50	41	73	785
6	13	12	30	58	619	12	19	19	17	73	790
8	7	41	6	58	624	14	13	47	53	74	794
10	2	9	42	58	628	16	8	16	29	74	799
11	20	38	18	59	632	18	2	45	5	74	804
13	15	6	54	59	637	19	21	13	40	75	808
15	9	35	30	60	641	21	15	42	16	75	813
17	4	4	6	60	646	23	10	10	52	76	817
18	22	32	42	60	650	25	4	39	28	76	822
20	17	1	18	61	655	26	23	8	4	76	827
22	11	29	54	61	659	28	17	36	40	77	831
24	5	53	30	62	663	30	12	5	16	77	836
26	0	27	6	62	668	Decembris.					
27	18	55	42	62	672	0	12	5	16	77	836
29	13	24	18	63	677	2	6	33	52	78	840
Octobris.						4	1	2	28	78	845
1	7	52	54	63	681	5	19	31	4	78	849
3	2	21	30	64	686	7	13	59	40	79	854
4	20	50	6	64	690	9	8	28	16	79	859
6	15	18	41	65	695	11	2	56	52	80	863
8	9	47	17	65	699	13	21	25	28	80	868
10	4	15	53	65	704	14	15	54	4	80	873
11	22	44	29	66	708	16	10	22	40	81	877
13	17	13	5	66	713	18	4	51	16	81	882
15	11	41	41	67	717	19	23	19	52	82	886
17	6	10	17	67	721	21	17	48	28	82	891
19	0	38	53	67	726	23	12	17	4	82	897
20	19	7	29	68	730	25	6	45	40	83	900
22	13	36	5	68	735	27	1	14	16	83	905
24	8	4	41	69	739	28	19	42	52	84	909
26	2	33	17	69	744	30	14	11	28	84	914
27	21	1	5	69	749						
29	15	30	29	70	753						

TAB. III. Aequationes Conjunctionum Primi Satellitis cum Jove.

Num. A.	Aequat. Conjunct. Adde.															
	Eq. Num. B.	Num. A.	Eq. Num. B.	Num. A.												
0	39	8	15	128	12	7	26	256	0	1	31	384	11	52	26	
4	38	12	16	132	11	27	26	260	0	0	31	388	12	37	26	
8	37	16	16	136	10	47	26	264	0	1	31	392	13	23	25	
12	36	21	16	140	19	9	27	268	0	3	31	396	14	11	25	
16	35	26	17	144	9	31	27	272	0	7	31	400	14	59	25	
20	34	30	17	148	8	45	27	276	0	12	31	404	15	48	24	
24	33	35	17	152	8	19	27	280	0	19	31	408	16	38	24	
28	32	40	18	156	7	44	28	284	0	28	30	412	17	30	24	
32	31	45	18	160	7	10	28	288	0	38	30	416	18	22	23	
36	30	50	19	164	6	38	28	292	0	50	30	420	19	15	23	
40	29	56	19	168	6	7	28	296	1	3	30	424	20	9	23	
44	29	3	19	172	5	37	28	300	1	17	30	428	21	4	22	
48	28	10	20	176	5	8	29	304	1	33	30	432	22	59	22	
52	27	16	20	180	4	41	29	308	1	50	30	436	22	55	22	
56	26	23	20	184	4	15	29	312	2	8	30	440	23	53	21	
60	25	30	21	188	3	49	29	316	2	28	30	444	24	51	21	
64	24	38	21	192	3	24	29	320	2	51	30	448	25	49	21	
68	23	47	21	196	3	1	29	324	3	15	29	452	26	48	20	
72	22	56	22	200	2	40	30	328	3	40	29	456	27	48	20	
76	22	5	22	204	2	20	30	332	4	6	29	460	28	48	19	
80	21	15	22	208	2	1	30	336	4	34	29	464	29	49	19	
84	20	26	23	212	1	42	30	340	5	3	29	468	30	50	19	
88	19	37	23	216	1	25	30	344	5	34	29	472	31	51	18	
92	18	48	23	220	1	10	30	348	6	5	28	476	32	53	18	
96	18	0	24	224	0	58	30	352	6	38	28	480	33	55	17	
100	17	14	24	228	0	47	30	356	7	13	28	484	34	57	17	
104	16	28	24	232	0	36	30	360	7	50	28	488	35	59	17	
108	15	42	24	236	0	26	30	364	8	27	27	492	37	1	16	
112	14	57	25	240	0	18	30	368	9	6	27	496	38	5	16	
116	14	13	25	244	0	12	31	372	9	46	27	500	39	8	15	
120	13	30	25	248	0	7	31	376	10	27	27	504	40	11	15	
124	12	48	26	252	0	4	31	380	11	9	26	508	41	15	14	
128	12	7	26	256	0	1	31	384	11	52	26	512	42	17	14	

TAB. III. Primæ Æquationes Conjunctionum Primi Satellitis cum Jove.

Num. A.	Æquat. Conjunct. Adde.			Æquat. Conjunct. Adde.			Æquat. Conjunct. Adde.			Æquat. Conjunct. Adde.			Æquat. Num. B.		
	I	II	III	A.	B.	C.	I	II	III	A.	B.	C.			
512	42	17	14	640	70	26	3	768	77	40	0	896	61	48	6
516	43	19	14	644	71	3	3	772	77	29	0	900	61	2	7
520	44	21	13	648	71	38	3	776	77	18	0	904	60	15	7
524	45	23	13	652	72	11	2	780	77	6	0	908	59	28	7
528	46	25	13	656	72	42	2	784	76	51	1	912	58	39	8
532	47	26	12	660	73	13	2	788	76	34	1	916	57	50	8
536	48	27	12	664	73	42	2	792	76	15	1	920	57	1	8
540	49	28	13	668	74	10	2	796	75	56	1	924	56	11	9
544	50	28	13	672	74	36	1	800	75	36	1	928	55	20	9
548	51	28	11	676	75	1	1	804	75	15	1	932	54	29	9
552	52	27	10	680	75	25	1	808	74	52	1	936	53	38	10
556	53	25	10	684	75	48	1	812	74	27	1	940	52	46	10
560	54	23	9	688	76	8	1	816	74	1	2	944	51	53	10
564	55	21	9	692	76	26	1	820	73	35	2	948	51	0	11
568	56	17	9	696	76	43	0	824	73	8	2	952	50	6	11
572	57	12	8	700	76	59	0	828	72	39	2	956	49	13	11
576	58	7	8	704	77	13	0	832	72	9	2	960	48	20	12
580	59	1	8	708	77	26	0	836	71	38	3	964	47	26	12
584	59	54	7	712	77	38	0	840	71	6	3	968	46	31	12
588	60	46	7	716	77	48	0	844	70	32	3	972	45	36	13
592	61	38	6	720	77	57	0	848	69	57	3	976	44	41	13
596	62	28	6	724	78	4	0	852	69	21	3	980	43	46	13
600	63	17	6	728	78	9	0	856	68	45	4	984	42	50	14
604	64	5	5	732	78	13	0	860	68	7	4	988	41	55	14
608	64	53	5	736	78	15	0	864	67	29	4	992	41	0	14
612	65	39	5	740	78	16	0	868	66	49	4	996	40	4	15
616	66	24	5	744	78	15	0	872	66	9	5	1000	39	8	15
620	67	7	4	748	78	12	0	876	65	28	5	1004	38	12	16
624	67	49	4	752	78	9	0	880	64	46	5	1008	37	16	16
628	68	30	4	756	78	4	0	884	64	3	5	1012	36	21	16
632	69	10	4	760	77	58	0	888	63	19	6	1016	35	26	17
636	69	49	3	764	77	50	0	892	62	34	6	1020	34	30	17
640	70	26	3	768	77	40	0	896	61	48	6	1024	33	35	17

TAB. IV. Secundæ Æquationes Conjunctionum Satellitum cum Jove, sive
Generalis Æquatio Luminis. Addendæ.

Num. B.	0	100	200	300	400	500	600	700	800	900
Æqu.	Æquat.									
	I	II								
0	14	0	12	52	9	45	5	30	1	37
4	14	0	12	46	9	36	5	20	1	30
8	13	59	12	40	9	26	5	9	1	23
12	13	59	12	35	9	17	4	59	1	16
16	13	58	12	29	9	7	4	48	1	9
20	13	57	12	23	8	58	4	38	1	3
24	13	56	12	17	8	48	4	28	0	57
28	13	54	12	11	8	38	4	18	0	52
32	13	53	12	4	8	28	4	8	0	46
36	13	51	11	56	8	17	3	58	0	40
40	13	49	11	49	8	7	3	48	0	35
44	13	47	11	42	7	57	3	38	0	31
48	13	44	11	34	7	47	3	29	0	27
52	13	41	11	27	7	36	3	19	0	23
56	13	38	11	20	7	26	3	9	0	19
60	13	36	11	13	7	16	2	59	0	16
64	13	33	11	5	7	5	2	50	0	13
68	13	29	10	57	6	55	2	41	0	10
72	13	25	10	49	6	44	2	32	0	7
76	13	20	10	40	6	33	2	24	0	5
80	13	16	10	31	6	22	2	15	0	4
84	13	21	10	21	6	11	2	7	0	3
88	13	7	10	12	6	1	1	59	0	10
92	13	2	10	3	5	51	1	52	0	1
96	12	58	9	54	5	40	1	44	0	0
100	12	52	9	45	5	30	1	37	0	0

Tertiæ Æquationes
Addendæ

T A B. V.
Semidurations Eclipſium Primi Satellitis Jovis.

Num. A.	Equa tiones.	Num. A.	Num. A.	Semidu- rationes.	Nu. A.	Semidu- rationes.	Nu. A.	Semidu- rationes.	Nu. A.	Semidu- rationes.									
	I	II		b. I	I	II	b. I	I	II	b. I	I	II							
0	3	30	1000	0	1	5	9	250	1	7	0	500	1	5	9	750	1	7	46
20	3	29	980	10	1	4	56	260	1	7	15	510	1	4	53	760	1	7	57
40	3	28	960	20	1	4	44	270	1	7	31	520	1	4	39	770	1	8	7
60	3	25	940	30	1	4	33	280	1	7	45	530	1	4	26	780	1	8	15
80	3	19	920	40	1	4	23	290	1	7	57	540	1	4	15	790	1	8	22
100	3	12	900	50	1	4	13	300	1	8	7	550	1	4	7	800	1	8	26
120	3	4	880	60	1	4	7	310	1	8	15	560	1	4	3	810	1	8	28
140	2	56	860	70	1	4	4	320	1	8	22	570	1	4	1	820	1	8	30
160	2	46	840	80	1	4	2	330	1	8	27	580	1	4	0	830	1	8	28
180	2	34	820	90	1	4	0	340	1	8	28	590	1	4	3	840	1	8	26
200	2	22	800	100	1	4	2	350	1	8	29	600	1	4	7	850	1	8	22
220	2	10	780	110	1	4	3	360	1	8	27	610	1	4	13	860	1	8	16
240	1	57	760	120	1	4	6	370	1	8	24	620	1	4	23	870	1	8	8
260	1	44	740	130	1	4	12	380	1	8	17	630	1	4	35	880	1	8	0
280	1	30	720	140	1	4	21	390	1	8	9	640	1	4	49	890	1	7	50
300	1	17	700	150	1	4	31	400	1	7	58	650	1	5	4	900	1	7	37
320	1	5	680	160	1	4	42	410	1	7	46	660	1	5	19	910	1	7	22
340	0	53	660	170	1	4	55	420	1	7	31	670	1	5	36	920	1	7	8
360	0	41	640	180	1	5	9	430	1	7	14	680	1	5	54	930	1	6	55
380	0	31	620	190	1	5	23	440	1	6	58	690	1	6	10	940	1	6	40
400	0	22	600	200	1	5	39	450	1	6	40	700	1	6	28	950	1	6	23
420	0	14	580	210	1	5	55	460	1	6	20	710	1	6	46	960	1	6	8
440	0	8	560	220	1	6	11	470	1	6	2	720	1	7	2	970	1	5	54
460	0	4	540	230	1	6	26	480	1	5	45	730	1	7	17	980	1	5	37
480	0	2	520	240	1	6	43	490	1	5	26	740	1	7	33	990	1	5	22
500	0	0	500	250	1	7	0	500	1	5	9	750	1	7	46	1000	1	5	9

The Use of the foregoing TABLES; or Precepts for computing, by them, the Times when the Immersions and Emerisions of Jupiter's First Satellite, happen under the Meridian of London.

1. IN the first Table, intituled, *Epochæ Conjunctionum Mediærum, &c.* look for the Year propos'd, and write out the Epochæ of the mean Conjunction, or the Day, Hour, Minute, and Second thereof, together with it's corresponding Numbers, A, and B.

2. In the second Table, intituled, *Revolutiones Primi Satellitis Jovis in Mensibus*, seek the Month in Question, and write out the Day, Hour, Minute, and Second, next less than the Time, on which the Eclipse sought, has already, or will hereafter happen; together with the Numbers A and B, annexed thereto.

3. Add the Numbers A together; and likewise the several Times collected from the Tables (by the first and second Precept) and the Sum of these will be the mean Time of the middle of the Eclipse required.

4. Enter the third Table, intituled, *Primiæ Æquationes Conjunctionum, &c.* with the Sum of the Numbers A, (obtained by the third Precept) rejecting the Thousands, and take out the first Equation of the Conjunctions answering thereto; and also the Equation of the Number B.

5. Add together all the several Numbers B, thus equated, (rejecting the Thousands) and write out the second Equation of the Conjunctions, answering to their Sum, from the fourth Table, intituled, *Secundæ Æquationes Conjunctionum, &c. five Generalis Æquatio Luminis.*

6. Enter the fifth, or last Table, intituled, *Tertiæ Æquationes & Semidurationes Eclipsum, &c.* with the former Sum of the Numbers A, (obtained by the third Precept) and write out the third Equation corresponding thereto; and likewise the Semi-Duration of the Eclipse, which is to be set down a-part.

7. To the mean Time of the middle of the Eclipse (obtained by the third Precept) add all the three Equations (found by the fourth, fifth, and sixth Precepts) and that Sum will discover the exact Time of the middle of the Eclipse.

8. If the Sum of the Numbers B, (Precept the fifth) is less than five Hundred, subtract the Semi-Duration of the Eclipse, from the Time before found (by the seventh Direction) and the

[30]

Remainder is the exact Time of the Immersion required: But if the Sum of the Numbers B, is greater than five Hundred, add the same to the former Time, and it will give the exact Time of the Emersion sought.

9. The Time obtained in this manner, is equal Time, which may be reduced to the apparent, or true, by the Tables of Equation of Time; that are every where to be met with.

Note, that in the Bissextile Year, after February, one Day must be subtracted from the Day of the Month.

We shall illustrate these Precepts by an Example or two, which will render them very plain and easy.

E X A M P L E I.

At Pekin in China, an Immersion of the First Satellite of Jupiter, was observed the 6th of January, 11^h 22^{min} 30^{sec} p. m. (O S) by Ign. Kogler. (Phil. Trans. No. 420. p. 182.) The Time when the same Eclipse happened under the Meridian of London, is required; and also the Difference of the Meridians of those Places.

	Y	D	H	I	!!	No. A.	No. B.
Epoch of the Conjunctions, (per Tab. 1.)	1730.	—	0	20	11	39	799 468
Revolutions of the 1 st Satellite, (per Tab. 2.)	January.	5	7	25	48	1	14
Mean Time of the Middle of the Eclipse	—	6	3	37	27	800	1 BEq.
1 st Equation (per Tab. 3.)	—	—	1	15	36		483
2 ^d Equation (per Tab. 4.)	—	—	—	0	3		
3 ^d Equation (per Tab. 5.)	—	—	—	2	22		
Exact Time of the Middle of the Eclipse, (Eq. Time)	6	4	55	28			
Semi-Duration Subtract	—	1	8	26			
Exact Time of the Immersion, (Eq. Time)	6	3	47	02			
Equation of Time, Subtract	—	10	45				
True Time of the Immersion at London	6	3	36	17			
True Time of the Immersion at Pekin (supra)	6	11	22	30			

Horary Difference of Meridians — 7 46 13 which, converted into Degrees of the Equator, gives 116 Deg. 13 Min. the Distance of the Meridian of Pekin from that of London: Wherefore, since the Time at London was less than at Pekin, the Longitude of Pekin, (according to this Observation) is 116 Deg. 13 Min. East from London.

E X A M -

E X A M P L E II.

At Pekin in China, an Emerson of the First Satellite of Jupiter, was observed the 3d of May 9^h 28' 45" p.m. (O S) by Ign. Kogler, (Phil. Trans. No. 420. p. 182.) The Time when the same Eclipse happened under the Meridian of London, is required; and also the Difference of the Meridians of those Places.

	Y	D	H	'	"	No. A.	No. B.
Epocha of the Conjunctions (per Tab. 1.)	1730	—	0	20	11 39	799	468
Revolutions of the 1st Satellite (per Tab. 2.)	May	—	2	2	53 21	28	309
Mean Time of the Middle of the Eclipse	—	—	2	23	05 00	827	—
1st Equation (per Tab. 3.)	—	—	—	1	12 46	—	779
2d Equation (per Tab. 4.)	—	—	—	—	8 56	—	—
3d Equation (per Tab. 5.)	—	—	—	—	2 38	—	—
Exact (Equal) Time of the Middle of the Eclipse	—	3	00	29	20	—	—
Semi-duration add	—	—	—	1	8 29	Semi-duration.	—
Exact (Equal) Time of the Emerson	—	3	1	37	49	1	8 29
Equation of Time add	—	—	—	—	4 4	—	—
True Time of the Immersion at London	—	3	1	41	53	—	—
True Time of the Immersion at Pekin (supra)	—	3	9	28	45	—	—
Horary Difference of Meridians	—	7	46	52	which, converted into Degrees of the Equator, gives 116 Deg. 23 Min. the Difference of the Meridians of Pekin and London: Wherefore, since the Time at London was less than at Pekin, the Longitude of Pekin, (according to this Observation) is 116 Deg. 23 Min. East from London.	—	—

F I N I S.

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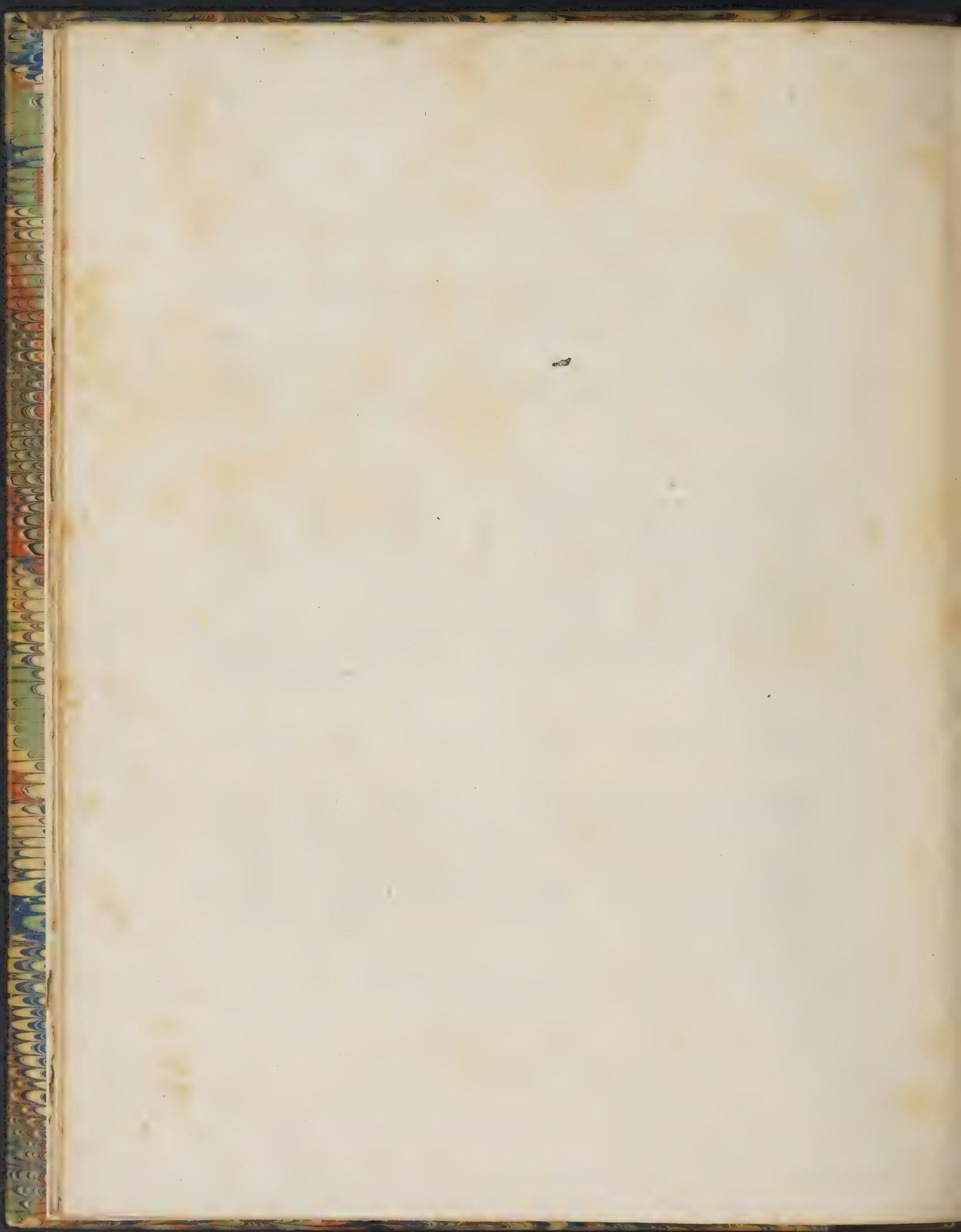
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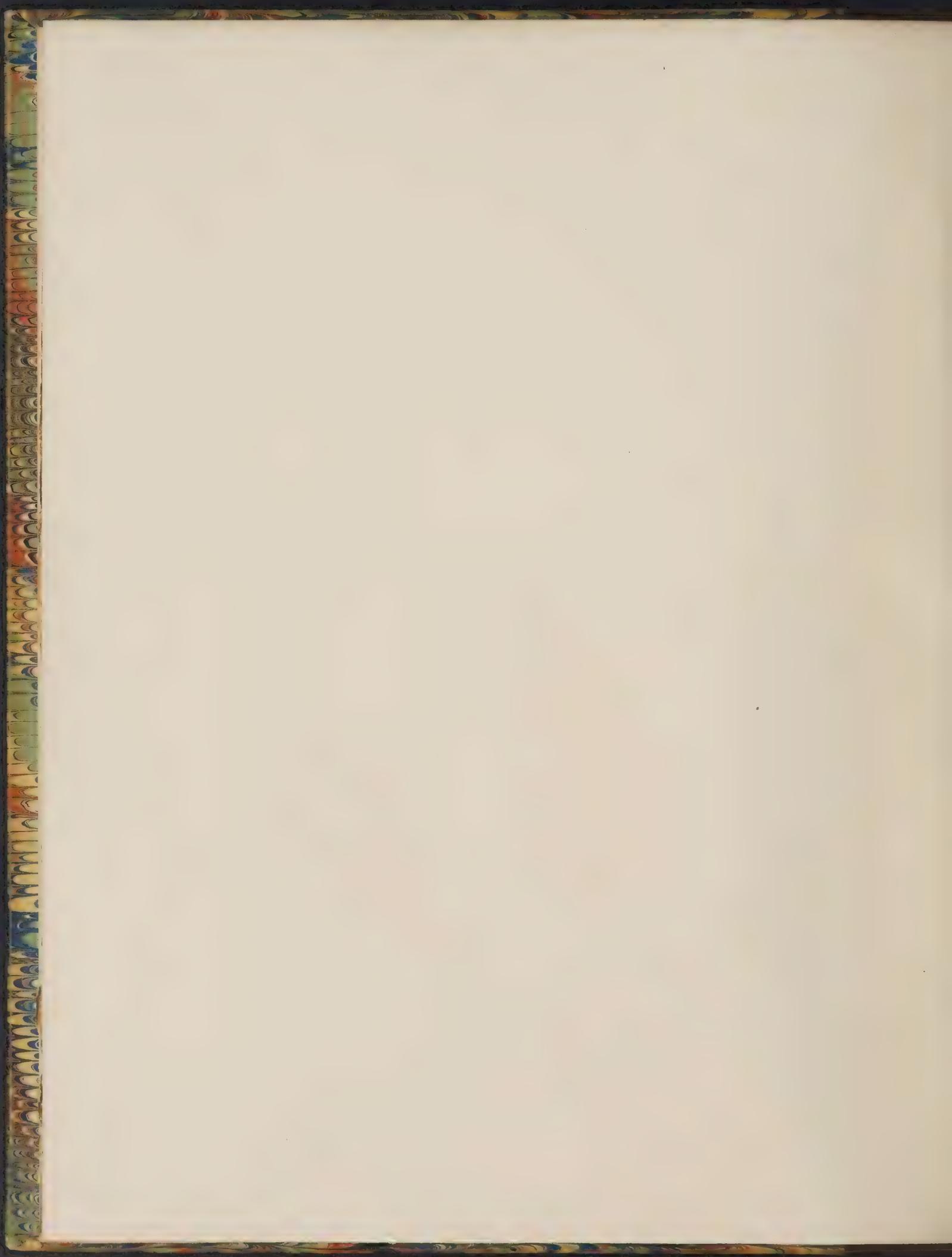
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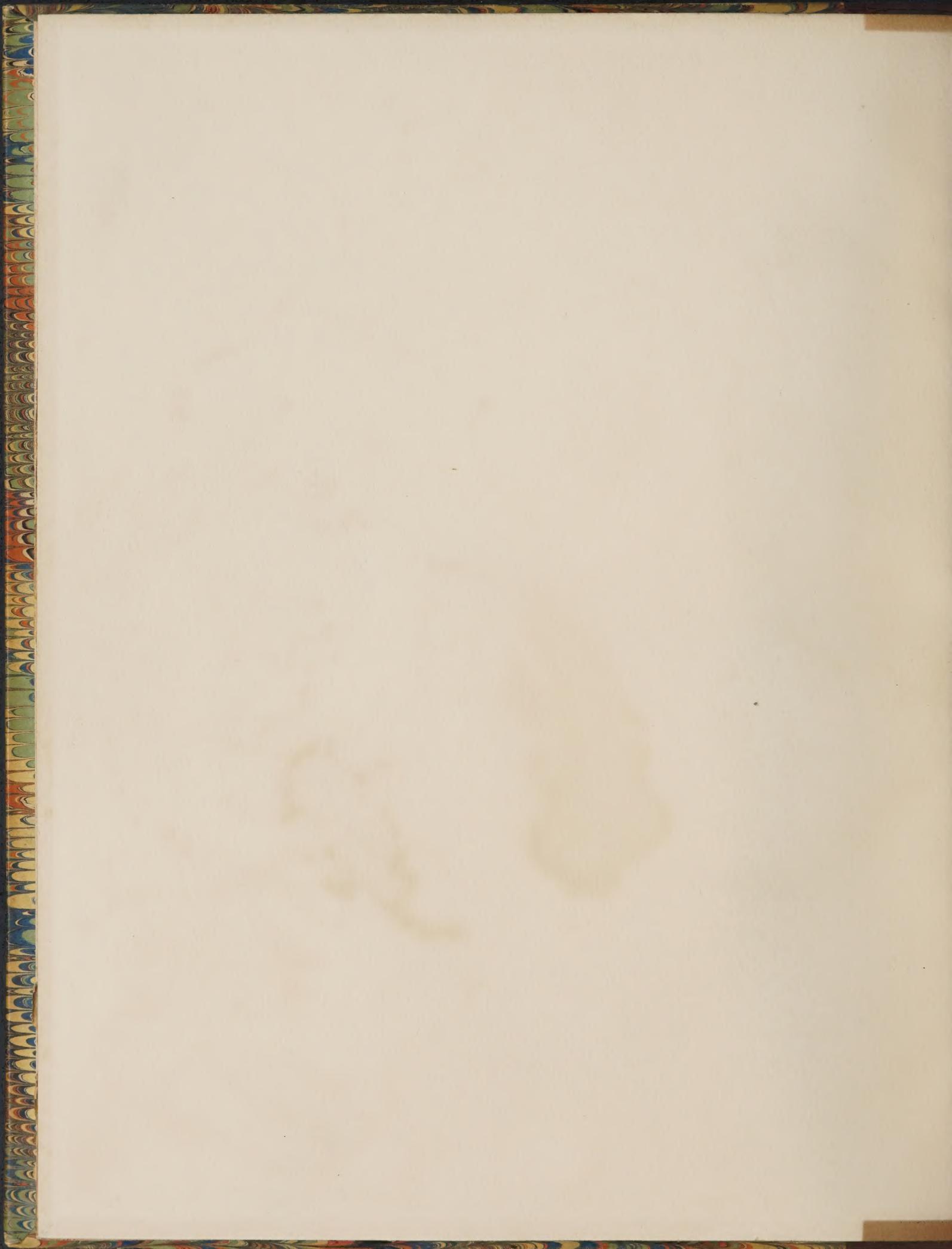
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